JPL-D-8545, REV A

JPL DERATING GUIDELINES

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JET PROPULSION LABORATORY

ELECTRONIC PARTS ENGINEERING OFFICE 507

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1.0 SCOPE

This document provides guidelines and recommendations for derating of electronic parts used in JPL spaceflight hardware. Significant portions of MIL-STD-975, Appendix A have been incorporated within this document. Due to the ongoing changes now being incorporated within the mil specifications including some cancellations, many of the references to MIL-STD-975 which appeared in previous versions of this document have been replaced by actual text from the mil standard. Obvious errors have been corrected and in some areas, new text has been prepared.

2.0 INTRODUCTION

Derating of a part is the intentional reduction of its electrical, mechanical and thermal stresses for the purpose of providing a safety margin between the applied stress and the actual demonstrated limit of the part capabilities. The derating policy established herein reduces the occurrence of stress related failures and helps assure long term reliability. Circuit designers and part users should evaluate all part applications and assure that adequate deratings have been accomplished. This document is available from the Electronic Parts Engineering Office and on Internet at the NASA EEE Parts Program home page (*http://nppp.jpl.nasa.gov/dmg/jpl/loc/derating.pdf*).

3.0 DERATING CRITERIA

The derating criteria contained herein apply to worst case values of electrical and environmental stresses expected during hardware qualification tests. The recommended derating factors are based on the best information currently available and do not preclude further derating. Note that in radiation environments, some part categories may require further derating.

Parts not appearing in these guidelines are lacking in empirical data and failure history. If derating information is needed for a specific part not appearing, consult the JPL Office 507 specialist.

3.1 CAPACITOR DERATING CRITERIA

Voltage derating for capacitors is accomplished by multiplying the maximum operating voltage by the appropriate derating factor.

Type	Military Style	Voltage Derating Factor 1/	Specification	Maximum Ambient Temperature 2/
Ceramic	CCR 3/ CKS CKR 3/ CDR 3/	0.60 0.60 0.60 0.60	MIL-C-20 MIL-C-123 MIL-C-39014 MIL-C-55681	110°C 110°C 110°C 110°C
Glass	CYR	0.50	MIL-C-23269	110°C
Plastic Film	CRH CHS	0.60 0.60	MIL-C-83421 MIL-C-87217	85°C 85°C
Tantalum, Foil	CLR25 CLR27 CLR35 CLR37	0.50 0.50 0.50 0.50	MIL-C-39006/1 MIL-C-39006/2 MIL-C-39006/3 MIL-C-39006/4	70°C 70°C 70°C 70°C
Tantalum, Wet Slug	CLR79 CLR81	0.60 0.40 0.60 0.40	MIL-C-39006/22 MIL-C-39006/25	70°C 110°C 70°C 110°C
Tantalum, Solid	CSR 4/ CSS 4/ CWR 4/	0.50 0.30 0.50 0.30 0.50 0.30	MIL-C-39003/1, /2 MIL-C-39003/10 MIL-C-55365	70°C 110°C 70°C 110°C 70°C 110°C

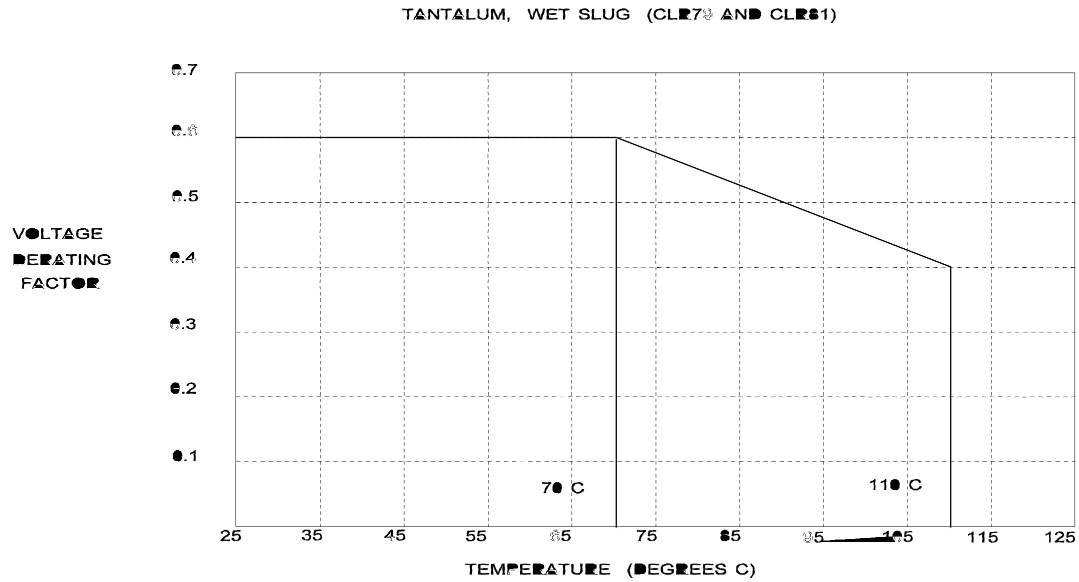
1/ The derating factor applies to the sum of peak AC ripple and DC polarizing voltages.

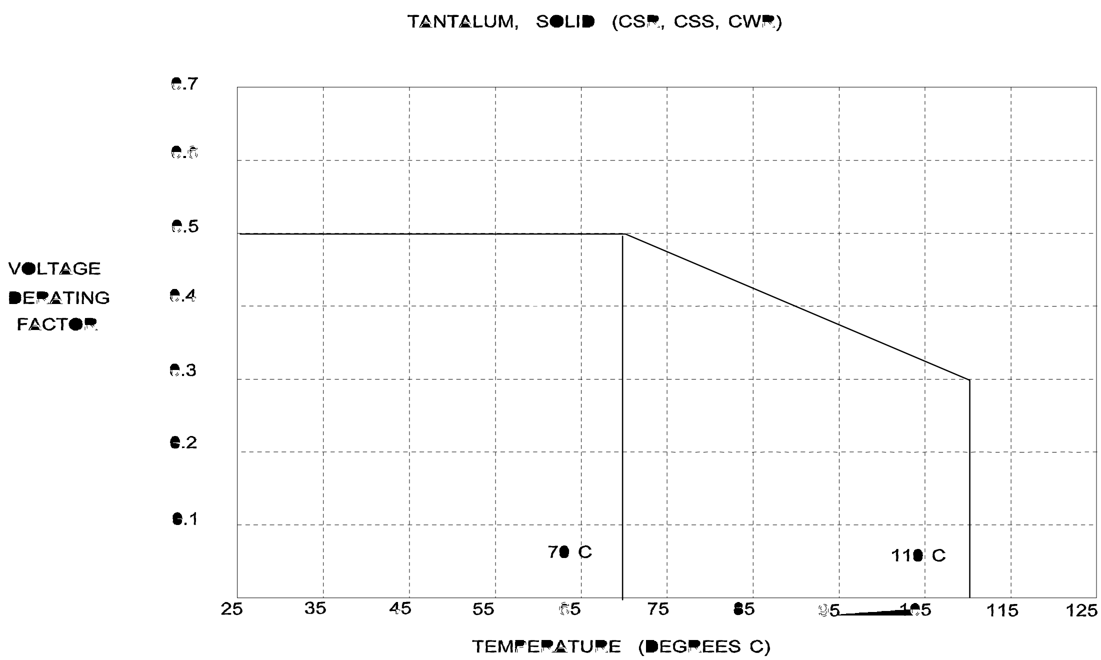
2/ Maximum ambient temperature applies to applications where capacitor is operating at or below maximum derated voltage. For operation above this temperature, consult part specialist for correct derating factor.

3/ For low voltage applications (< 10 Vdc), rated voltage should be at least 100 Vdc.

4/ For applications where the effective circuit resistance is less than 1 ohm per volt, contact the part specialist.

3.1.1 Capacitor Derating Graphs





3.1.2. Capacitor Derating Example

The principal stress parameters for capacitors are temperature and DC and/or AC voltage.

Examples 1: A CYR style glass capacitor rated at 10 pF, 100 Vdc is operated at a maximum of 70°C ambient temperature.

Applying the 0.50 derating factor results in a maximum derated operating voltage of 50 Vdc.

The 70°C ambient temperature is within the maximum allowed.

Example 2: A 100 Vdc, CLR79 capacitor is operated at a maximum ambient temperature of 85°C.

The chart for Tantalum wet slug CLR79 capacitors shows a voltage derating factor of 0.52 at 85°C resulting in a maximum derated operating voltage of 52 Vdc.

3.2 CRYSTAL AND CRYSTAL OSCILLATOR DERATING CRITERIA

Crystal oscillator derating should be accomplished by derating the individual components to the recommended values. Crystals should be derated to 50% of the maximum rated current.

3.3 DIODE DERATING CRITERIA

Derating for diodes is accomplished by multiplying the critical stress parameter by the appropriate derating factor. Junction temperature should be calculated and maintained at or below the specified maximum.

Diode Type	Critical Stress Parameter	Derating Factor	Maximum Junction Temperature
General Purpose, Rectifier, Switching, Pin/Schottky and Thyristors	PIV Surge Current Forward Current	0.70 0.50 0.50	1/
Power Schottky Rectifiers	PIV Surge Current Forward Current	0.70 0.50 0.50	1/
Varactors	Power Reverse Voltage Forward Current	0.50 0.75 0.75	1/
Voltage Regulators	Power Zener Current	0.50 $0.5(I_{ZMAX} + I_{ZNOM})$	1/
Voltage Reference Diodes	Zener Current	2/	1/
Transient Absorption Zener (TAZ)	Power Dissipation	0.50	1/
FET Current Regulator Diode	Peak Operating Voltage	0.50	1/

1/ Maximum Junction temperatures for all diode types should be limited to 110°C or to 40°C below the manufacturer's rating, whichever is lower.

2/ Operate at manufacturer's specified I_{ZT} to optimize temperature compensation.

3.3.1 Diode Derating Example

For diodes, junction temperature, voltage and current are the principle stress parameters with high junction temperature being the most destructive.

Example: A general purpose diode rated at 1A, 200V is operating at an ambient temperature of 30°C. Thermal resistance, junction to ambient is given as 175°C/W.

Applying derating criteria:

Current = 0.5 x 1A = 0.5A.
PIV = 0.7 x 200V = 140V

Note that maximum forward voltage (typically 1V), and derated forward current (0.5A) results in a power dissipation of 0.5W.

Calculating junction temperature:

$T_J = (R_{TH(J\text{-}A)} \times P_D) + T_A$
$T_J = 175°C/W \times 0.5W + T_A = 87.5°C + 30°C = 117.5°C$

This exceeds the allowable derated T_J of 110°C.

Reducing forward current to 0.45A and recalculating:

W = 0.45 X 1V = .45W
$T_J = 175°C/W \times 0.45W + T_A = 78.75°C + 30°C = 108.75°C$.

3.4 FILTER DERATING CRITERIA

Filters are derated by multiplying the critical stress parameter by the appropriate derating factor.

Filter Type	Critical Stress Parameter	Derating Factor	Maximum Ambient Temperature
ALL	Rated Current	0.50	85°C
	Rated Voltage	0.50	

3.5 INDUCTOR DERATING CRITERIA

Inductors are derated by reducing operating temperature based on the insulation class used and by reducing maximum rated operating voltage. See notes below.

Insulating Class		Maximum Operating Parameters		
MIL-C-39010	MIL-C-15305	Rated Operating Temperature	Derated Operating Temperature	Operating Voltage
-	O	85°C	65°C	1/
A	A	105°C	85°C	
B	B	125°C	105°C	
F	-	150°C	130°C	

1/ Derate operating voltage to 50% of rated dielectric withstanding voltage.

Notes:

a) Maximum operating temperature is defined as ambient temperature plus temperature rise of the winding plus a 10°C allowance for hot spot. Temperature rise is calculated as follows:

Temperature Rise Test (see MIL-T-27, Para. 4.8.12)
Temperature Rise(°C) = (R - r) / r (t + 234.5°C) - (T - t)

Where R = winding resistance at elevated temperature.
r = winding resistance at ambient temperature.
t = initial ambient temperature (°C).
T = maximum ambient temperature (°C) at time of power shutdown.
Note: T should not differ from t by more than 5°C.

b) Maximum rated operating temperatures specified in the table are based on a life expectancy of 10,000 hours. The derated operating temperatures are selected to extend life expectancy to 50,000 hours.

c) Custom made inductors should be evaluated on a materials basis to establish maximum rated operating temperature. This temperature should then be derated by a factor of 0.75.

3.5.1 Inductor Derating Example:

Parameters to be derated are maximum dielectric stress voltage and operating temperature.

Example: An inductor is to be constructed to MIL-C-39010 using Class B insulation. Dielectric withstanding voltage will be rated at 100V.

Applying derating criteria:

Maximum operating voltage = .5 X 100V = 50V.

Calculating temperature rise where R = 17Ω winding resistance at elevated temperature (T) of 30°C and r = 15Ω at ambient temperature (t) of 25°C.

$$
\begin{aligned}
T_{RISE} &= (R - r) / r\ (t + 234.5°C) - (T - t) \\
&= (17 - 15) / 15\ (25°C + 234.5°C) - (30°C - 25°C) \\
&= (0.133)\ (259.5°C) - 5°C \\
&= 34.5°C - 5°C = 29.5°C
\end{aligned}
$$

Maximum operating temperature = T_A + T_{RISE} + 10°C (hot spot temperature) = 25°C + 29.5°C + 10°C = 64.5°C

This is well within the maximum derated operating temperature of 105°C for class B insulation and in fact as seen in the table, class A insulation would be sufficient.

3.6 LINEAR MICROCIRCUIT DERATING CRITERIA

Derating of linear microcircuits is accomplished by multiplying the parameter by the appropriate derating factor specified below.

Critical Stress Parameters	Comparators	Sense Amplifiers	Operational/ Differential Amplifiers	Other Amplifiers 1/	Voltage Regulators	Analog Switches	A/D and D/A Converters
Absolute Maximum Supply Voltage	0.80	0.80	0.80	0.80	0.80	0.80	0.80
Differential Input Voltage 2/	0.70	0.70	0.70 3/	0.70	N/A	N/A	N/A
Single-Ended DC Input Voltage 2/	N/A	N/A	N/A	N/A	0.80	0.80	0.80
Power Dissipation 4/	0.75	0.75	0.75	0.75	0.75	0.75	0.75
Open Collector/Drain DC Output Voltage	0.75	0.75	N/A	N/A	N/A	N/A	N/A
Operating AC or DC Output Current	0.80	0.80	0.80	0.80	0.80	0.80	0.80
Maximum Short Circuit Output Current	0.80	0.80	0.80	0.80	0.80	N/A	N/A
Maximum Junction Temperature	5/	5/	5/	5/	5/	5/	5/

1/ Other amplifiers include Current, Voltage Follower, Instrumentation, Video and Sample and Hold.

2/ Under no circumstances shall input voltage be allowed to exceed the supply voltage.

3/ Derate by at least 2V below the absolute maximum voltage rating of each rail.

4/ Power dissipation derating factor pertains to the percent of rated power at maximum rated junction temperature. Calculation of the maximum power dissipation at the maximum derated junction temperature shall be considered preferable.

5/ Junction temperatures should be limited to 110°C maximum or 40°C below the manufacturer's rating, whichever is lower.

3.6.1 Linear Microcircuit Derating Example

The principal stress parameters for linear microcircuits are supply voltage, input voltage, output current, total device power and junction temperature. Note that package thermal rating will effect the junction temperature and limit the output current and power allowed.

Example: A uA741 op amp is rated as follows:

V_{CC} (supply voltage) = ±22 Vdc max
V_{ID} (differential input voltage) = ±30 Vdc max
I_{OS} (output short circuit current) = 60 mA max
T_J = 175°C max
P_D = 500 mW max @ T_A = 25°C.
$R_{TH(J-A)}$ (thermal resistance, junction to ambient) = 158°C/W (TO-5 package)
Derate at - 6.3 mW/°C above 70°C.

Applying the derating criteria from the Operational/Differential Amplifiers column of Table II:

V_{CC} = +17.6 Vdc max	(0.8 X 22 Vdc)
V_{EE} = -17.6 Vdc max	(0.8 X 22 Vdc)
V_{ID} = ±21 Vdc max	(0.7 X 30 Vdc
I_{OS} = 48 mA	(0.8 X 60 mA)
T_J = 110 °C	(max allowed)
P_D = 375 mW	(0.75 X 500 mW)

Operating the junction at 110°C with a worst case T_A of 80°C the maximum allowed device power dissipation is:

$$P_D = (T_J - T_A) / R_{TH\ (J-A)} = (110°C - 80°C) / 158°C/W = 30/158 = 190 \text{ mW}$$

Note that when maximum P_D is calculated based on T_J = 110°C, the calculation of the derated P_D (0.75 X max rated) is not applicable.

3.7 DIGITAL MICROCIRCUIT DERATING CRITERIA

Derating of digital microcircuits is accomplished by multiplying the parameter by the appropriate derating factor specified below.

Critical Stress Parameters	Bipolar	CMOS		Line Drivers/ Receivers	LSI/VLSI		Gate Arrays Bipolar/MOS
		4000 A/B	HC/AC Series		Bipolar	CMOS	
Maximum Supply Voltage 1/ 2/	3/	0.70	0.80	0.75	3/	3/	0.80
Open Collector/Drain DC Output Voltage	0.80	0.80	0.80	0.80	0.80	0.80	0.80
Operating AC/DC Output Current or Fanout	0.80	0.80	0.80	0.80	0.80	0.80	0.80
Maximum Junction Temperature	4/	4/	4/	4/	4/	4/	4/

1/ Under no circumstances shall input voltage be allowed to exceed the supply voltage.

2/ For those technologies where no supply voltage derating is specified, in no case shall the device maximum rated supply voltage be exceeded.

3/ Use Manufacturer's recommended operating voltages.

4/ Junction temperatures should be maintained at 110°C maximum or 40°C below the manufacturer’s rating, whichever is lower.

3.7.1 Digital Microcircuit Derating Example

The principal stress parameters for digital microcircuits are supply voltage, output current (fanout), total device power and junction temperature. Note that package thermal rating will effect the junction temperature and limit the output current and power allowed.

Example: A TTL5402 quad two-input nor gate is rated as follows:

V_{CC} (supply voltage) = 7.0 Vdc
I_{CC} (supply current) = 27 mA
V_{IH} (input high) = 2.0 Vdc min
V_{IL}(input low) = 0.8 Vdc max
V_{OH} (output high) = 2.4 Vdc min
V_{OL}(output low) = 0.4 Vdc max
I_{OL} = 16 mA each output
Fanout = 10 (I_{IL} = 1.6 mA per input)
T_J = 175°C max; $R_{TH(J-C)}$ = 28°C/W (14 pin cerdip)

Calculating worst case package power:

$V_{CC} = 5.0 \pm 0.5$ Vdc (Mfg recommended operating voltage); I_{CC} = 27 mA.
$P_D = V_{CC} \times I_{CC}$ = 5.5 V X 27 mA = 148.5 mW

V_{OL} = 0.4 V; I_{IL} = 1.6 mA; Fanout = 8 (Derated max value)
P_D = 8 (0.4V X 1.6 mA) X 4 (quad device) = 20.48 mW

Total worst case dissipated power = 148.5 + 20.48 = 168.98 mW

Note: For MOS operation also calculate and add the AC max dissipated power wattage contribution and delete the fanout.
Operating the junction at 110°C and assuming their is no contribution from ambient air (no convection) in space environment:

$$T_J = [\, P_D \times R_{TH\ (J-C)} \,] + T_C$$

Note that $P_D \times R_{TH\ (J-C)}$ = 0.16898W X 28°C/W = 4.73°C temperature rise.
T_J = 110°C and 110°C - 4.73°C = 105.3°C T_C which is the maximum allowable case temperature for the part.

Also note that the maximum dissipated power must be decreased as case temperature increased to maintain T_J below 110°C.

3.8 PROTECTIVE DEVICES DERATING CRITERIA (FUSES/CIRCUIT BREAKERS)

Derating of protective devices is accomplished by multiplying the current rating by the appropriate derating factor specified below.

A. Fuses

Current Rating (AMPS)	Derating Factor 1/ 2/	Comments
2 - 15	0.50	Fuse current ratings are at 25°C ambient. Above 25°C, derating factors should be decreased an additional 0.5%/°C.
1, 1.5	0.45	
0.5, 0.75	0.40	Derating of fuses allows for loss of pressure, which lowers the blow current rating and allows for a decrease of current capability with time.
0.375	0.35	
0.25	0.30	
0.125	0.25	

1/ If calculations result in fractional values, use the next highest standard fuse rating.

2/ Derating factors are based on data from fuses mounted on printed circuit boards and conformally coated. For other types of mounting, consult the part specialist for recommendations.

B. Circuit Breakers

Contact Application	Contact Current Derating Factor	Maximum Ambient Temperature
Resistive	0.75	20°C below maximum rated temperature.
Capacitive	0.75 1/	
Inductive	0.40	
Motor	0.20	
Filament	0.10	

1/ Use series resistance to assure that circuits do not exceed the derated value.

3.8.1 Protective Device Derating Examples

For fuses, the principal stress parameter is current.

Example 1: A board expecting to be operated at an ambient temperature of 80°C. Maximum current is calculated to be 0.9A.

Fuse derating factor is 50% plus additional derating of 0.5%/°C for an increase in ambient temperature above 25°C.

Calculating derating factor:

DF = 0.5 - [.005 X (80°C - 25°C)] = 0.5 - 0.275 = 0.225

Calculating fuse rating:

0.90/0.225 = 4A

A fuse rated at 4A or greater should be used for this circuit.

For circuit breakers, the principal stress parameter is contact current. Derating level is predicated on application load.

Example 2: A circuit is to be selected to control a motor rated at 24Vdc and a full load current of 17A. The circuit breaker is to be installed in an environment where ambient temperature ranges from 10°C to 30°C.

Calculating contact current rating:
17A/.20 = 85A

Calculating circuit breaker temperature rating:
30°C + 20°C = 50°C

This application requires a circuit breaker with a contact current rating of 85A and an operating temperature rating of 50°C.

3.9 RELAY AND SWITCH DERATING CRITERIA

The derated contact current (I_{DR}) is determined by multiplying the contact current rating and the product of T, R and L taken from the following tables.

$$I_{DR} = I \times T \times R \times L$$

Note that the relay criteria established here is acceptable assuming that any inductive kick voltages produced from inductive loads will be properly suppressed to not exceed 120% of rated contact voltage at rated contact current.

Switches should be derated to 80% of rated contact load current at rated contact load voltage.

Table T (Ambient Operating Temperature)

Temperature Range	-65°C to -21°C	-20°C to +39°C	+40°C to +84°C	+85°C to +125°C
Derating Factor	0.85	0.90	0.85	0.70

Table R (Cycle Rate)

Cycle Rate per hour	<1.0	1.0 to 10	>10
Derating Factor	0.85	0.90	0.85

Table L (Load Application)

Load Application	A (to 0.5 sec.)	B (to 5 min.)	C (other)
Derating Factor	1.0	1.5	0.8

Load A - Make Break and/or carry loads with on-time duration of 0 to 500 milliseconds and off-time $\geq$ on time.

Load B - Carry only loads (relay contacts are closed before there is current flowing through the contacts and current is not interrupted by the contacts). Relay does not make or break the load. Maximum on-time is 5 minutes; off-time is $\geq$ on-time.

Load C - Make, break and/or carry. Those loads that do not fall into the category of loads A or B. (Limited use).

3.9.1 Relay Derating Examples

The principal stress parameters are continuous contact current, peak contact current and duration, contact voltage, type of load, number of operating cycles and operating temperature. Using reduced coil voltages and abnormal contact voltages can reduce the life of the relay and compromise relay operation.

Example 1: A relay with contact current rating of 1A is operating at an ambient temperature of 70°C. The relay is cycled at a rate of 5 cycles per hour. The load application is make, break and carry with on/off time durations of 400 msec.

To determine maximum derated contact current, I_{DR}:

From Table T, select the +40°C to +84°C temperature factor (0.85).
From Table R, select the 1 to 10 cycles/hour cycle rate factor (0.90).
From Table L, select load application factor A (1.0)

I_{DR} = I X T X R X L = 1A X 0.85 X 0.90 X 1.0 = 0.765A

Example 2: A 10A relay is operating at an ambient temperature of -40°C. The relay is cycled on for three minutes once every 2 hours. The load application is carry-only.

Select the appropriate factors from the tables.

Calculate maximum derated contact current:

I_{DR} = I X T X R X L = 10A X 0.85 X 0.85 X 1.5 =10.84A

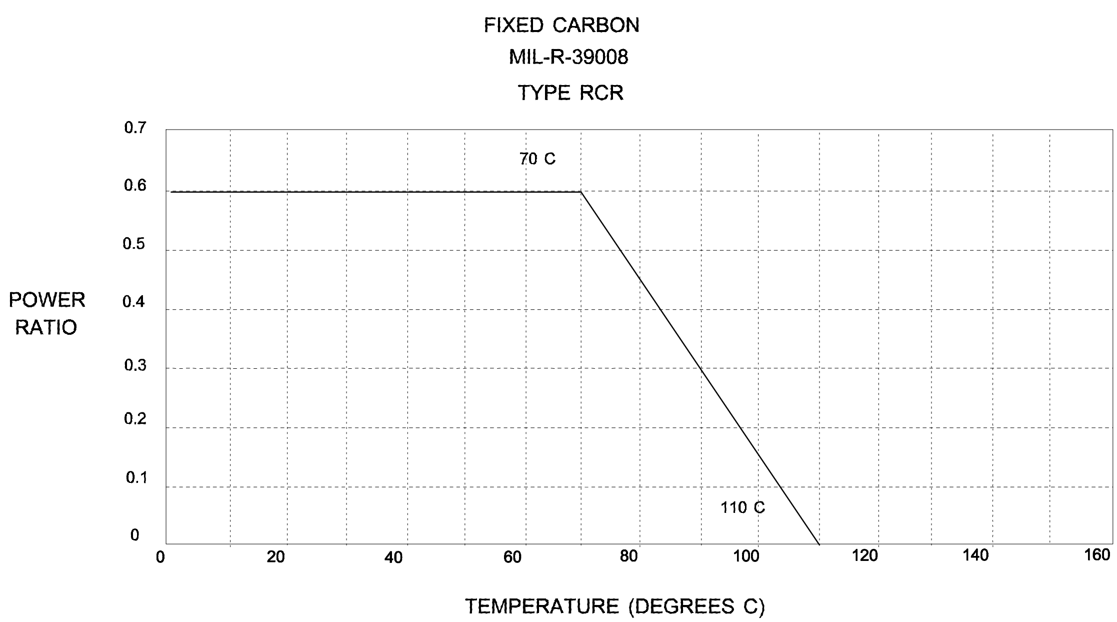
3.10 RESISTOR DERATING CRITERIA

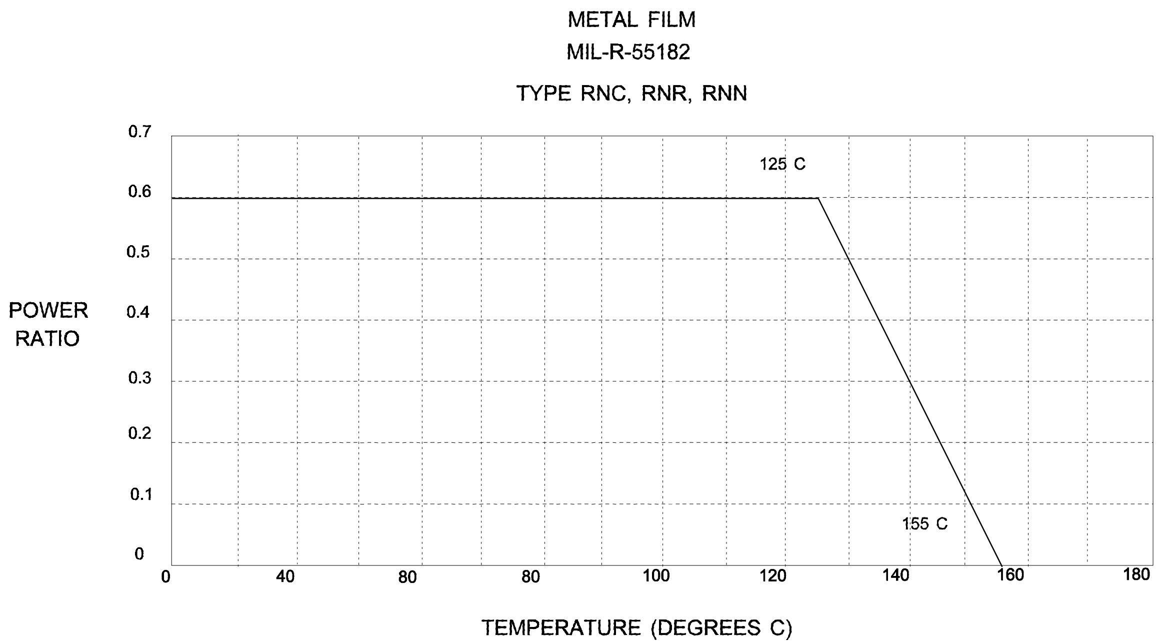
The derated power level of a resistor is obtained by multiplying the resistor's maximum rated power by the appropriate power ratio found on the (y) axis in the following graphs. This ratio is also a function of the resistor's maximum ambient temperature as shown in the (x) axis.

Maximum applied voltage should not exceed 80% of maximum rated voltage. Where no maximum voltage is specified, applied voltage should be limited to $0.8\sqrt{PR}$ where P is maximum rated power and R is nominal resistance.

This voltage derating applies to DC and regular waveform AC applications. For pulse and other irregular waveforms consult the applicable military specification or manufacturer's data.

3.10.1 Resistor Derating Graphs

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MIL-R-55182
TYPE RNC, RNR, RNN
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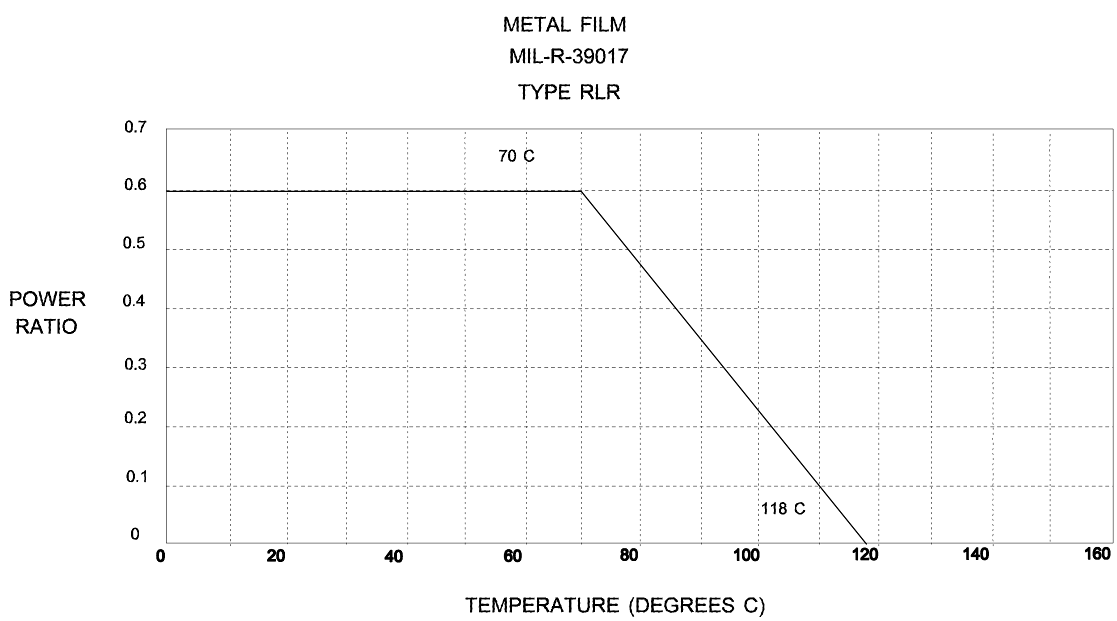
0.6
0.5
0.4
0.3
0.2
0.1
0
POWER RATIO
125 C
155 C
0
40
80
80
100
120
140
160
180
TEMPERATURE (DEGREES C)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0.6
0.5
0.4
0.3
0.2
0.1
0
POWER RATIO
70 C
118 C
0
20
40
60
80
100
120
140
160
TEMPERATURE (DEGREES C)

FIXED WIRE WOUND
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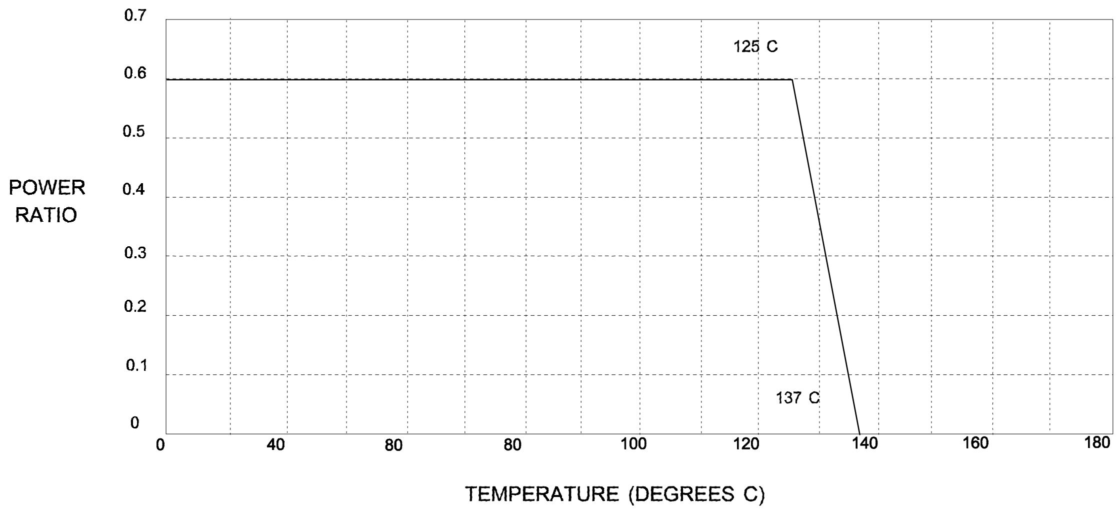
TYPE RBR



VARIABLE WIRE WOUND
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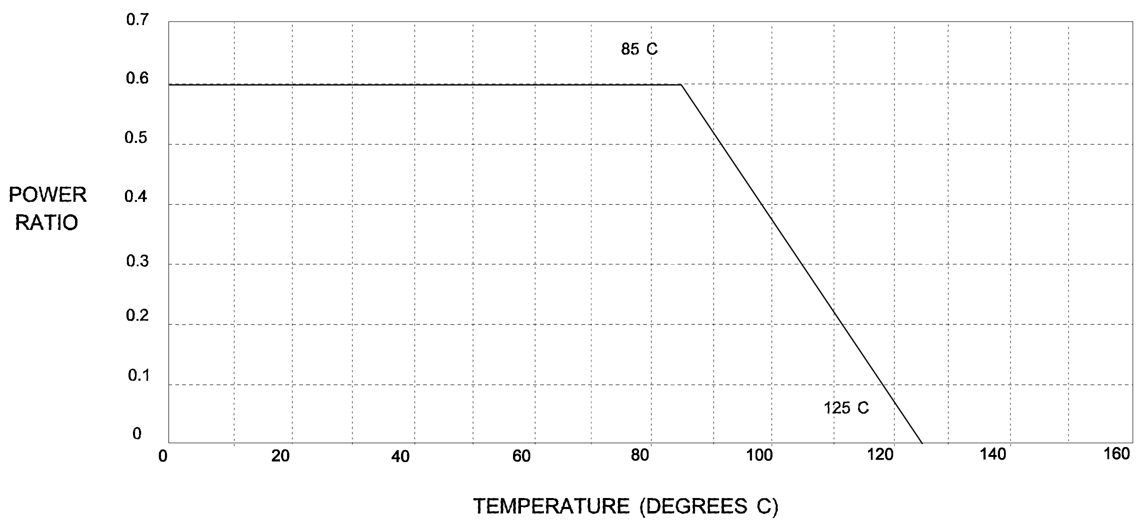

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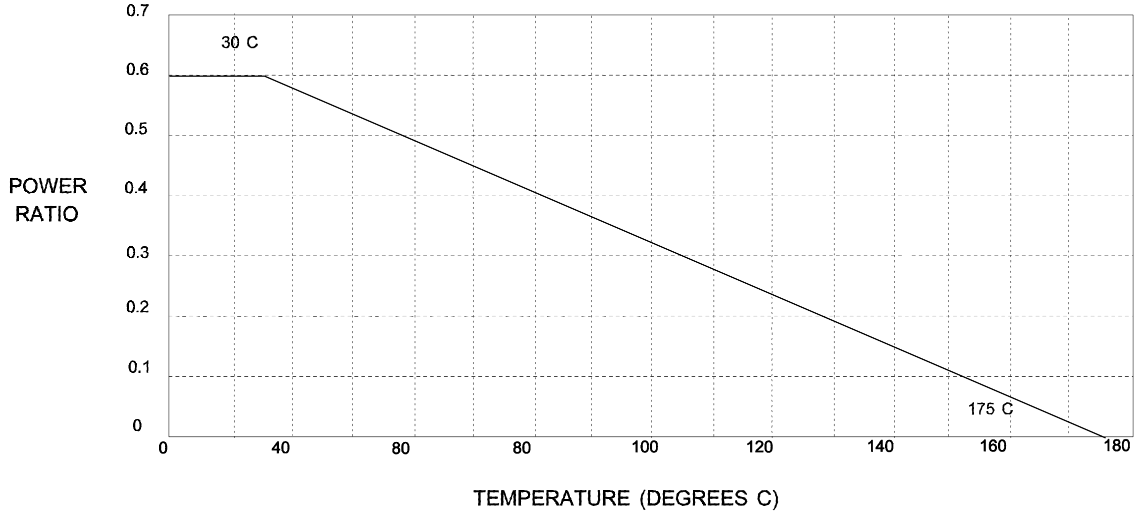
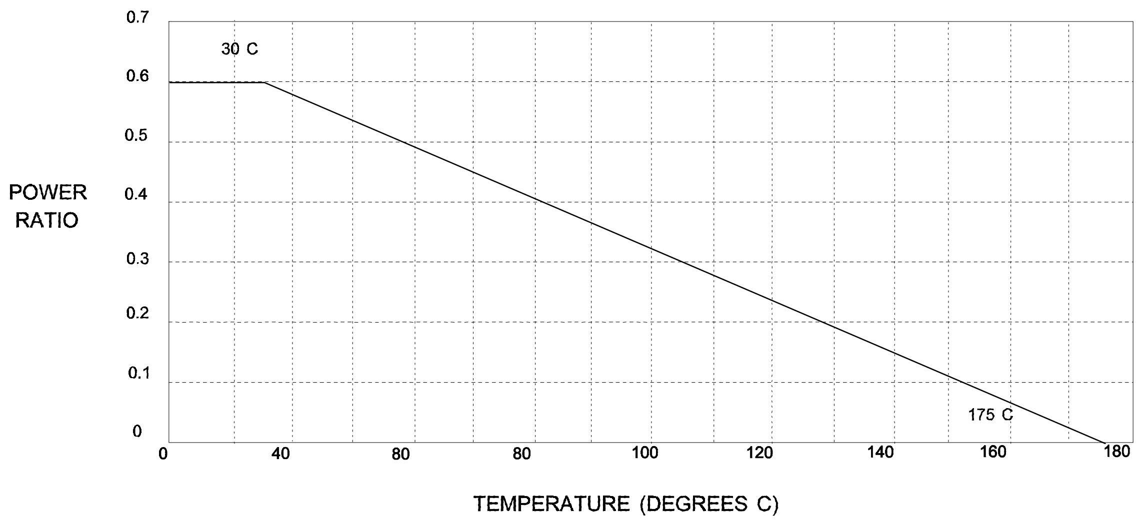
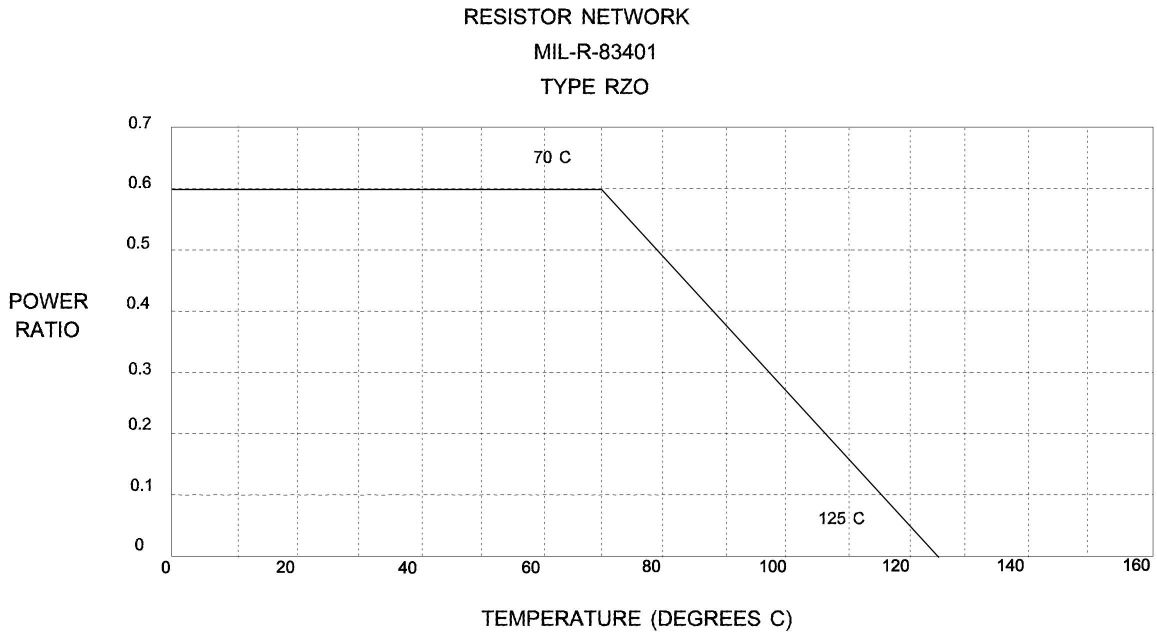


POWER FIXED WIRE WOUND
MIL-R-39009
TYPE RER

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TYPE RZO
POWER
RATIO
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0.6
0.5
0.4
0.3
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0.1
0
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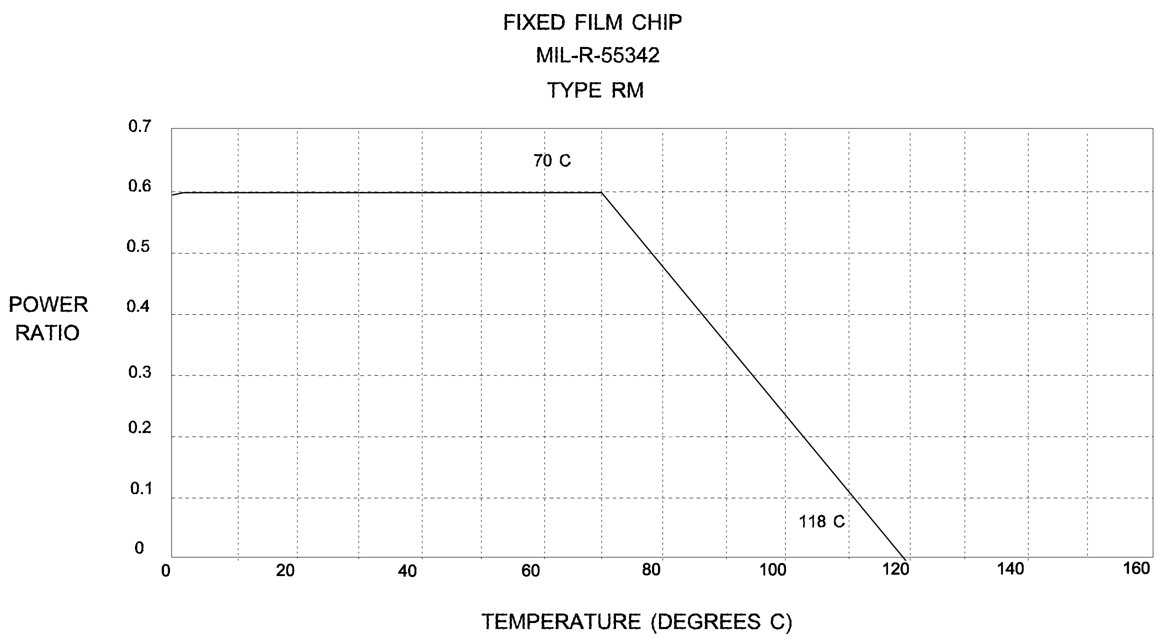
125 C
0
20
40
60
80
100
120
140
160
TEMPERATURE (DEGREES C)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MIL-R-55342
TYPE RM
POWER
RATIO
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0.6
0.5
0.4
0.3
0.2
0.1
0
70 C
118 C
0
20
40
60
80
100
120
140
160
TEMPERATURE (DEGREES C)

3.10.2 Resistor Derating Examples

Power, voltage and ambient temperature are the principal stress parameters.

Example 1: A 0.5W metal film, RNR70 type resistor is used in an application where the ambient temperature is 130°C.

The derating graph for RNR type resistors indicates that at 130°C, this resistor should be derated to 0.5 times its rated power.

For this application, resistor current must be limited to maintain power at 0.25W maximum.

Example 2: A 0.1W metal film type RNC55H4753FP resistor is used in an application where the ambient temperature is 100°C.

The graph for RNC type resistors indicates that at 100°C, this resistor should be derated to 0.6 times rated power or 0.06 W.

This resistor has a resistance value of 475KΩ and a maximum voltage specified at 200V.

At the derated power level of 0.06W the applied voltage is:

$$E = \sqrt{PR} = \sqrt{\ } \, 0.06 \text{ X } 475\text{K} = 168.8\text{V}$$

This exceeds the maximum allowable voltage of 160V (0.8 X 200V). Therefore power dissipation must be reduced to:

$$P = E^2R = 160^2 \text{ X } 475\text{K} = 0.54\text{W which is } 0.54 \text{ X rated power.}$$

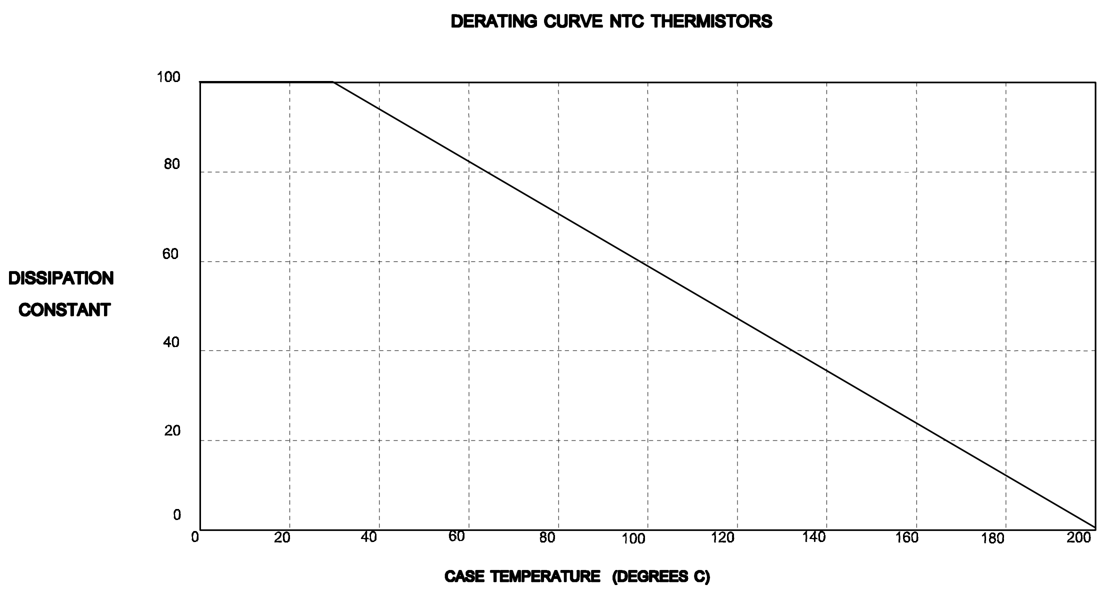
3.11 THERMISTOR DERATING CRITERIA

Applied voltage should not exceed 80% of maximum rated.

$E = 0.8\sqrt{PR}$ where P is maximum rated power and R is nominal resistance.

Positive Temperature Coefficient (PTC) thermistors are generally operated in the self-heat mode. Derate to 50% of rated power.

Negative Temperature Coefficient (NTC) thermistors, when operated in the self heat mode, can reach a point where the self-heating current causes a resistance drop resulting in more self-heating eventually leading to a thermal runaway condition. To prevent this occurrence, NTC thermistors should be derated to a power level causing a maximum increase of 50 times the dissipation constant, or a maximum part temperature of 100°C, whichever is less. (See graph below).



3.11.1 Thermistor Derating Example

Power and ambient temperature are principal stress parameters.

Example: A 0.15W NTC thermistor rated at 5000Ω at 25°C has an operating temperature range of -40°C to 200°C and a dissipation constant of 0.8mW/°C.

For power derating, multiply the dissipation constant by 50.

$$50 \times 0.8\text{mW/°C} = 40\text{mW}$$

The derating curve indicates that at 40mW dissipation, the part case temperature is limited to 125°C.This exceeds the maximum allowable derated case temperature of 100°C so, as stated in the derating criteria, 100°C should be used.

3.12 TRANSFORMER DERATING CRITERIA

Transformers are derated by reducing operating temperature based on the insulation class used and by reducing maximum rated operating voltage. See notes below.

Insulating Class		Maximum Operating Parameters		
MIL-T-27	MIL-T-21038	Rated Operating Temperature	Derated Operating Temperature	Operating Voltage
Q	Q	85°C	65°C	1/
R	R	105°C	85°C	
S	S	130°C	105°C	
V	T	155°C	130°C	
T	U	170°C	155°C	

1/ Derate operating voltage to 50% of rated dielectric withstanding voltage.

Notes:

a) Maximum operating temperature is defined as ambient temperature plus temperature rise of the winding plus a 10°C allowance for hot spot. Temperature rise is calculated per the Temperature Rise Test of MIL-T-27 as described below.
Temperature rise(°C) = (R - r) / r (t + 234.5°C) - (T - t)

Where R = winding resistance at elevated temperature.
r = winding resistance at ambient temperature.
t = initial ambient temperature (°C).
T = maximum ambient temperature (°C) at time of power shutdown.
Note: T should not differ from t by more than 5°C.

b) Maximum rated operating temperatures specified in the table are based on a life expectancy of 10,000 hours.The derated operating temperatures are selected to extend life expectancy to 50,000 hours.

c) Custom made transformers should be evaluated on a materials basis to establish maximum rated operating temperature. This temperature should then be derated by a factor of 0.75.

3.12.1 Transformer Derating Example

Parameters to be derated are maximum dielectric stress voltage and operating temperature.

Example: A 110 VAC / 24 Vac step down transformer is to be constructed to MIL-T-27 using Class Q insulation. Operating Temperature will be 40°C ambient. Dielectric withstanding voltage will be rated at 100V.

Calculating temperature rise where R = 2.95Ω winding resistance at elevated temperature (T) of 30°C and r = 2.5Ω at ambient temperature (t) of 25°C.

$$
\begin{aligned}
T_{RISE} &= (R - r) / r\ (t + 234.5°C) - (T - t) \\
&= (2.95 - 2.5) / 2.5\ (25°C + 234.5°C) - (30°C - 25°C) \\
&= (0.18)\ (259.5°C) - 5°C \\
&= 46.7°C - 5°C = 41.7°C
\end{aligned}
$$

Maximum operating temperature = $T_A + T_{RISE}$ + 10°C (hot spot temperature) = 40°C + 41.7°C + 10°C = 91.7°C

Since the derated maximum operating temperature for Class Q insulation is only 65°C, Class S insulation (105°C) should be used.

The dielectric withstanding voltage of the insulation should be rated at 220 VAC(220 VAC X 50% = 110 VAC).

3.13 TRANSISTOR DERATING CRITERIA

Derating for transistors is accomplished by multiplying the critical stress parameter by the appropriate derating factor. Junction temperature should be calculated and maintained at or below the specified maximum.

Transistor Type	Critical Stress Parameter	Derating Factor	Maximum Junction Temperature
BI Polar General Purpose Switching Chopper Unijunction Power	Power Current Voltage 1/	0.50 0.75 0.75	2/
Field Effect J FET MOS-FET (small signal) Power MOS FET	Power Current Voltage 1/	0.50 0.75 0.75	2/

1/ Voltage derating factor applies to worst case combination of DC, AC and transient voltages.

2/ Maximum junction temperatures for all transistor types should be limited to 125°C or to 40°C below the manufacturer's maximum rating, whichever is lower.

3.13.1 Transistor Derating Example:

Junction temperature is the most destructive stress for transistors. Power, voltage and current must also be derated.

Example: A 2N6756 MOSFET power transistor has the following maximum ratings.

Power (P_D) = 30W at T_C = 100°C ($R_{TH(J-c)}$ 1.67°C/W)

Current (I_D) = 14A

Voltage (V_{DS}) = 100V

Voltage (V_{GS}) = 20V

Derated Maximum Values:

P_D = 0.5 X 30W = 15W at T_C = 100°C

I_D = 0.75 X 14A = 10.5A

V_{DS} = .75 X 100 = 75V

V_{GS} = .75 X 20 = 15V

During the application, maximum P_D is calculated at 13W. Case temperature is determined to be 85°C .

Calculating junction temperature:

$T_J = (R_{TH(J-c)})\ (P_D) + T_c$

T_J = (1.67°C/W X 13W) + Tc = 21.7°C + 85°C = 106.7°C

3.14 OPTOELECTRONIC DEVICE DERATING CRITERIA

Derating is accomplished by multiplying the appropriate stress parameter by its derating factor. Junction temperature must also be calculated and maintained at or below the specified maximum value.

Device Type	Critical Stress Parameter	Derating Factor	Maximum Junction Temperature
Light Emitting Diodes	Power Current Voltage	.50 .75 .75	2/
Photo Diodes, Photo Transistors	Power Current Voltage	.50 .75 .75	2/
Optocouplers 1/	Power Current Voltage	.50 .75 .75	2/

1/ For optimum coupling efficiency, use manufacturers recommended operating conditions.

2/ Maximum junction temperatures for optoelectronic devices should be limited to 95°C or to 25°C below the manufacturer's maximum rating, whichever is lower.

3.14.1 Optoelectronic Device Derating Example

The principal stress parameters for optoelectronic devices are voltage, current, total device power dissipation and junction temperature.

Example: A 4N49 optocoupler has the following maximum ratings:

I_F (diode input current) = 40 mA
I_C (collector current) = 50 mA
V_{CEO} (collector-emitter voltage) = 40 Vdc
V_{CBO} (collector-base voltage) = 45 Vdc
V_{EBO} (emitter-base voltage) = 7 Vdc
T_J = 125°C max
P_D = 300 mW max @ T_A = 25°C.
$R_{TH(J-A)}$ (thermal resistance, junction to ambient) = 333°C/W
Derate at - 3 mW/°C

Applying the derating criteria from Table IV:

I_F = 30 mA	(.75 X 40 mA)
I_C = 37.5 mA	(.75 X 50 mA)
V_{CEO} = 30 Vdc	(.75 X 40V)
V_{CBO} = 33.75 Vdc	(.75 X 45V)
V_{EBO} = 5.25 Vdc	(.75 X 7V)
T_J = 95°C	(max allowed)
P_D = 150 mW	(.5 X 300 mW)

Operating the junction at 95°C with a worst case T_A of 60°C the maximum allowed device power dissipation is:

$$P_D = T_J - T_A / R_{TH\ (J-A)} = 95°C - 60°C / 333°C/W = 35 / 333 = 105\ mW$$

Note that when maximum P_D is calculated based on T_J = 95°C, the calculation of the derated P_D (0.50 X max rated) is not applicable.